



Symbols and Constants

F	force	V	
Q	charge	\vec{A}	
\vec{E}	electric field	ρ	
\vec{D}	displacement field	I	current
\vec{P}	polarization field	\vec{j}	current density
\vec{H}	magnetic field	ϵ_R	relative permittivity
\vec{B}	magnetic flux density field	μ_R	relative permeability
\vec{M}	magnetization	$\epsilon_0 \approx 8.85 \times 10^{-12}$	F/m
Φ	magnetic flux	$\mu_0 = 4\pi \times 10^{-7}$	N/A ²

Vector Calculus

cross products:

Cartesian	$\vec{a}_x \times \vec{a}_y = \vec{a}_z$	$\vec{a}_y \times \vec{a}_z = \vec{a}_x$	$\vec{a}_z \times \vec{a}_x = \vec{a}_y$
cylindrical	$\vec{a}_\rho \times \vec{a}_\phi = \vec{a}_z$	$\vec{a}_\phi \times \vec{a}_z = \vec{a}_\rho$	$\vec{a}_z \times \vec{a}_\rho = \vec{a}_\phi$
spherical	$\vec{a}_r \times \vec{a}_\theta = \vec{a}_\phi$	$\vec{a}_\theta \times \vec{a}_\phi = \vec{a}_r$	$\vec{a}_\phi \times \vec{a}_r = \vec{a}_\theta$

volume elements:

Cartesian	$dx dy dz$
cylindrical	$\rho d\rho d\phi dz$
spherical	$r^2 \sin \theta dr d\theta d\phi$

curl (cylindrical)

$$\vec{\nabla} \times \vec{A} = \left[\frac{1}{\rho} \frac{\partial \vec{A}_z}{\partial \phi} - \frac{\partial \vec{A}_\phi}{\partial z} \right] \vec{a}_\rho + \left[\frac{\partial \vec{A}_\rho}{\partial z} - \frac{\partial \vec{A}_z}{\partial \rho} \right] \vec{a}_\phi + \frac{1}{\rho} \left[\frac{\partial(\rho \vec{A}_\phi)}{\partial \rho} - \frac{\partial \vec{A}_\rho}{\partial \phi} \right] \vec{a}_z$$

curl (spherical)

$$\vec{\nabla} \times \vec{A} = \frac{1}{r \sin \theta} \left[\frac{\partial(A_\phi \sin \theta)}{\partial \theta} - \frac{\partial A_\theta}{\partial \phi} \right] \vec{a}_r + \frac{1}{r} \left[\frac{1}{\sin \theta} \frac{\partial A_r}{\partial \phi} - \frac{\partial(r A_\phi)}{\partial r} \right] \vec{a}_\theta + \frac{1}{r} \left[\frac{\partial(r A_\theta)}{\partial r} - \frac{\partial A_r}{\partial \theta} \right] \vec{a}_\phi$$

Electrostatics

Coulomb's law

$$\vec{F}_2 = \frac{Q_1 Q_2}{4\pi\epsilon_0 R^2} \vec{a}_{12}$$

\vec{E} of point charge

$$\vec{E} = \frac{Q \vec{a}_r}{4\pi\epsilon_0 r^2}$$

\vec{E} of charge distribution	$\vec{E} = \int_V \frac{\rho(\vec{r}') dV'}{4\pi\epsilon_0 \vec{r} - \vec{r}' ^2} \frac{\vec{r} - \vec{r}'}{ \vec{r} - \vec{r}' }$
Gauss's law	$\oint_S \vec{E} \cdot d\vec{S} = Q_{\text{enclosed}}^{\text{total}} = \int_V \rho dV$
	$\oint_S \vec{D} \cdot d\vec{S} = Q_{\text{enclosed}}^{\text{free}} = \int_V \rho_{\text{free}} dV$
	$\oint_S \vec{P} \cdot d\vec{S} = -Q_{\text{enclosed}}^{\text{bound}} = -\int_V \rho_{\text{bound}} dV$
relating \vec{E} to V	$\vec{E} = -\vec{\nabla}V$
relating V to \vec{E}	$V_{AB} = -\int_B^A \vec{E} \cdot d\vec{l}$
V of charge distribution	$V = \int_V \frac{\rho(\vec{r}') dV'}{4\pi\epsilon_0 \vec{r} - \vec{r}' }$
capacitance	$C = Q/V$
parallel plate capacitor	$C = \frac{\epsilon_0 \epsilon_R A}{d}$ of dimensions A and d
Poisson's equation	$\nabla^2 V = -\rho / \epsilon_0 \epsilon_R$
Laplace's equation	$\nabla^2 V = 0$
linear dielectrics	$\vec{D} = \epsilon_0 \epsilon_R \vec{E}$
boundary conditions	E_T and D_N continuous
energy	$W = \frac{1}{2} \int_V \vec{E} \cdot \vec{D} dV$

Magnetostatics

law of Biot-Savart	$\vec{H} = \oint \frac{I d\vec{l} \times \vec{a}_R}{4\pi R^2}$
law of Biot-Savart	$\vec{H} = \int_V \frac{\vec{j} \times \vec{a}_R dV}{4\pi R^2}$
Ampere's law	$\oint \vec{H} \cdot d\vec{l} = I_{\text{enclosed}}$
inductance	$L = N\phi / I$
vector potential	$\vec{A} = \int_V \frac{\mu_0 \vec{j} dV}{4\pi R}$

relating \vec{B} to \vec{A}	$\vec{B} = \vec{\nabla} \times \vec{A}$
linear materials	$\vec{B} = \mu_0 \mu_R \vec{H}$
boundary conditions	H_T and B_N continuous
energy	$W = \frac{1}{2} \int_V \vec{B} \cdot \vec{H} dV$

Electromagnetics

Maxwell's equations	$\vec{\nabla} \cdot \vec{D} = \rho$	$\vec{\nabla} \cdot \vec{B} = 0$
	$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$	$\vec{\nabla} \times \vec{H} = \vec{j} + \frac{\partial \vec{D}}{\partial t}$
Faraday's law	$\text{emf} = -d\Phi / dt$	
Poynting vector	$\vec{P} = \text{Re}(\vec{E}) \times \text{Re}(\vec{H})$	

Transmission lines

propagation constant	$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)} = \alpha + j\beta$
characteristic impedance	$Z_0 = \sqrt{(R + j\omega L)/(G + j\omega C)}$
reflection coeff.	$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$
transmission coeff.	$T = \Gamma + 1$
input impedance	$Z_{in} = Z_0 \frac{Z_L + jZ_0 \tan \beta l}{Z_0 + jZ_L \tan \beta l} \quad l \geq 0$
	$Z_{in} = Z_0 \frac{1 + \Gamma e^{-j2\beta l}}{1 - \Gamma e^{-j2\beta l}} \quad l \geq 0$
	$\beta = 2\pi / \lambda$
propagation velocity	$v = \omega / \beta$
standing wave ratio	$\text{SWR} = (1 + \Gamma) / (1 - \Gamma)$